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Published in:
International Journal of Science Education

DOI:
10.1080/09500693.2019.1675197

Publication date:
2019

International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: https://www.tandfonline.com/loi/tsed20

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To cite this article: Annelotte Lammers, Martin J. Goedhart & Lucy Avraamidou (2019) Reading and synthesising science texts using a scientific argumentation model by undergraduate biology students, International Journal of Science Education, 41:16, 2323-2346, DOI: 10.1080/09500693.2019.1675197

To link to this article: https://doi.org/10.1080/09500693.2019.1675197

Published online: 20 Oct 2019.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION
2019, VOL. 41, NO. 16, 2323–2346
https://doi.org/10.1080/09500693.2019.1675197

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Reading and synthesising science texts using a scientific argumentation model by undergraduate biology students

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ABSTRACT

This study reports about biology undergraduates' writing in a course with genre-based writing instruction. The students read, analyse and synthesise research articles using the Scientific Argumentation Model (SAM), a tool to make explicit the characteristics of the research article genre. We explored to what extent 21 students make a synthesis when writing a review of two research articles and which research article's genre characteristics (rhetorical moves and qualifiers) they use. We defined a synthesis as a task in which students select, organise, and connect the articles' content. The analysis of students' reviews showed that most students made a synthesis of both articles. The articles' objective, supports and main conclusion were mostly reflected in the students' reviews. Most students did not use a qualifier in their final conclusion, and when they did use a qualifier it sometimes did not correspond to their main text, suggesting difficulties with understanding the rhetorical meaning of qualifiers. We suggest, supported by our interview and questionnaire data, that SAM could be useful for understanding, selecting, and organising research articles' content when writing a review. We conclude that the use of SAM could be a first step in synthesising research articles focused on supporting students' rhetorical consciousness.

ARTICLE HISTORY
Received 3 December 2018
Accepted 29 September 2019

KEYWORDS
Genre-based writing instruction; reading; scientific writing; synthesis writing; undergraduate biology students

Introduction

In scientific discourse, the research article is the predominant genre (Penrose & Katz, 2004; Yarden, Norris, & Phillips, 2015). As science writers, scientists need to have knowledge of the content and understanding of the nature of the scientific discourse and its text genres to present their claims in a way that convinces readers. Hence, scientists need to be aware of the rules and conventions used in the discourse of their science discipline appropriate with their writing goal(s) and audience (Yore, Florence, Pearson, & Weaver, 2006). It is then crucial that university students pursuing science studies are supported in developing their scientific writing skills in order to enculturate themselves as member of the scientific community. Developing students'

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scientific writing skills becomes even more crucial in light of research evidence that scientific writing promotes scientific literacy (Jiménez-Aleixandre & Erduran, 2008; Norris & Phillips, 2003; Treacy & Kosinski-Collins, 2011), science learning (Choi, Hand, & Greenbowe, 2013), as well as academic and professional success (Breeze, 2012; Newell et al., 2011).

However, research has shown that writing science texts is a complex and demanding task for students (Kellogg, 2008; Rijlaarsdam et al., 2012). As well-documented in related literature, students encounter different kinds of writing difficulties, such as structuring, constructing arguments and expressing information accurately (Daems & van der Westen, 2008; Galbraith & Rijlaarsdam, 1999; Kelly, Regev, & Prothero, 2008; Sampson & Clark, 2008). Moreover, students may encounter difficulties when entering a new discourse community in which they will come across many different text genres. Often there is a misalignment between faculty and students in their expectations for writing (Lea & Street, 1998). Therefore, university instructors should immerse students in scientific discourse and educate students about the scientific genres and their characteristics. One way to support students in their writing is using genre-based writing instruction to explicitly draw their attention to the goals of discourse and its genres (Galbraith & Rijlaarsdam, 1999; Hyland, 2003; Swales, 1990). However, empirical research examining undergraduate students' science writing abilities using genre-based instruction is limited. This study aims to contribute to filling this gap by investigating the genre characteristics that undergraduate students use in their written science texts, following their participation in a science course that follows genre-based writing instruction.

Theoretical and empirical underpinnings

Teaching practices in scientific writing

In higher education writing courses have become common practice over the last decades (Björk, Bräuer, Rienecker, & Stray Jörgensen, 2003; Wingate, Andon, & Cogo, 2011). Of great influence is the *Writing Across the Curriculum* (WAC) movement in US colleges and universities, where academic writing instruction is embedded in all subject areas next to a common first-year composition course. Students are often supported by a (extra-curricular) writing centre (Bazerman et al., 2005; Russell, Lea, Parker, Street, & Donahue, 2009). *Writing in the Disciplines*, an approach within the WAC movement, is particularly concerned with discipline-specific writing instruction. Writing instruction is often delivered by subject teachers (Bazerman et al., 2005; Wingate & Tribble, 2012). In Europe, such an integration of writing instruction in disciplines is not common practice yet (Björk et al., 2003; Raad voor de Nederlandse Taal en Letteren, 2015). Examples of initiatives to embed writing instruction in science courses have been published. Some focused on writing-to-learn activities for undergraduates to construct science understanding (Reynolds, Thaiss, Katkin, & Thompson, 2012), while others focused on learning to write scientifically (Rice, 1998) or combined both (Cronje, Murray, Rohlinger, & Wellnitz, 2013). However, structural writing instruction is not always explicit or even absent in science undergraduate degree programmes (Herelixka & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015; Tribble & Wingate, 2013).

Reading-writing integration

Writing has often been viewed as an isolated skill, but more recently it is viewed to interact with other literacy skills and especially reading (Breeze, 2012). There has been a continued research interest exploring the ways reading and writing might strengthen content learning and support literacy and language development (Grabe, 2003; Spivey, 1997). Both skills share a set of knowledge (e.g. knowledge about text attributes, such as text organisation) and rely on correlated cognitive processes (Fitzgerald & Shanahan, 2000). Writing instruction should therefore be closely tied to reading and content instruction (Breeze, 2012; Grabe, 2001; Leki & Carson, 1997). Grabe (2003) called for more research towards reading-writing relations with more attention to genre knowledge and its uses in academic writing. Understanding and recognising a text structure in reading a text can improve writing (Grabe, 2001, 2003) and in turn, understanding a text's structure can improve reading comprehension (Grabe & Zhang, 2016). Swales (1990) coined the term *rhetorical consciousness* as the recognition of a genre's rhetorical structure. Swales stated that it is important to point to this structure when learning about a (text) genre. Built within these claims, in this study we combined reading and writing activities in order to support students in developing their rhetorical consciousness. In universities reading-based writing is common, often referred to as *writing from sources* (Grabe & Zhang, 2016). An example of a small-scale writing task combining reading and writing is the *academic reaction* paper, which prompts students to read, summarise, and critically evaluate a research article (Breeze, 2012). A more complex reading-based writing task is the *discourse synthesis*. It requires students to compose a text by selecting, organising, and connecting content from multiple sources (Cumming, Lai, & Cho, 2016; Segev-Miller, 2004; Spivey, 1997; Zhang, 2013). In our study, we used a *synthesis writing* task (literature review) in order to integrate reading and writing in a course that follows genre-based writing instruction principles to acquaint students with the genre characteristics of research articles.

Genre-based writing instruction

Learning to write genres is like a process of apprenticeship in a new academic setting (Berkenkotter & Huckin, 1995), enculturating students into the practices of scientists (Norris & Phillips, 2003). Genre-based writing instruction is supposed to develop students' genre knowledge (De La Paz & McCutchen, 2011; Hyland, 2007; Tardy, 2009a). Genre knowledge is a form of 'situated cognition' and is defined as 'an individual's repertoire of situationally appropriate responses to recurrent situations' (Berkenkotter & Huckin, 1995, p. ix). De La Paz and McCutchen (2011) argued that, although the importance of students' genre knowledge is growing, there is a lack of empirical research that examines students' genre knowledge. Similarly, Hyland (2003, 2007) argued for the use of genre-based writing instruction, because it helps students perform the literacy tasks during their degree programme and beyond. In addition, a genre-based approach is useful for students who do not have much experience in writing (Dudley-Evans, 1997) as is the case for the participants in this study. A genre-based approach aims at giving students control over a genre by familiarising them with its rhetorical characteristics and social contexts to gain access to the discourse community (Hyland, 2007). An important underlying belief in genre-based writing instruction is that explicit knowledge of the rhetorical and linguistic features of a genre supports students in learning how to write that particular genre (Hyland, 2003; Tardy, 2009b).

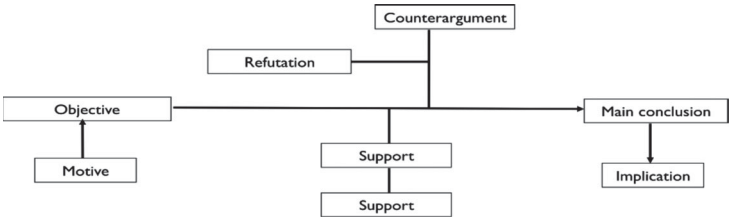
For the purpose of this study, we draw primarily on a genre-based approach that evolves from English for Specific Purposes (ESP), largely influenced by John Swales (1990). This genre-based writing instruction is mainly focused on non-native speakers of English in academic settings, as is the case for the participants in this study, and is concerned with teaching explicitly the textual and linguistic genre features (Hyon, 1996; Swales & Feak, 1994). Students, often in small groups, analyse and compare samples of a genre: a process called *rhetorical consciousness raising* (Hyland, 2007). In the present study we used the research article genre, predominant in scientific discourse, and introduced students explicitly to its characteristics by using a heuristic following the principles of genre-based writing instruction.

Research article genre characteristics

The rhetorical nature of science is reflected in a research article's text (Florence & Yore, 2004; Penrose & Katz, 2004). Its most obvious characteristic is the canonical text structure, often called *IMRD* (Introduction, Method, Results, Discussion) (Yarden et al., 2015). The typical line of reasoning within a research article from a research question to data and their interpretations to support the claims is denoted as *argumentative structure* (Bazerman, 1988; Suppe, 1998). Within this line of reasoning, the authors construct an argument as the justification of a claim by data (Toulmin, 1958). From a genre analysis perspective, a line of reasoning in a research article is reflected in its *rhetorical structure*, the specific arrangement of rhetorical moves. *Rhetorical moves* are defined as text fragments fulfilling a specific communicative function, present in the different sections playing an important role in the argumentation. An example is the research question in the introduction (Connor, Upton, & Kanoksilapatham, 2007; Swales, 1990; Van Lacum, Koeneman, Ossevoort, & Goedhart, 2016).

As we reported in previous work, a way to support undergraduate students' rhetorical consciousness in reading is to make use of the Scientific Argumentation Model (SAM) (Van Lacum et al., 2016; Van Lacum, Ossevoort, & Goedhart, 2014). This heuristic was developed to help science undergraduates read and understand the argument in research articles focusing explicitly on the rhetorical structure of a research article. SAM consists of a set of seven rhetorical moves in research articles and their characteristics, and a scheme that shows the relationships between the moves (Van Lacum et al., 2016). Van Lacum et al. (2014) found that the use of SAM helped students to read research articles. The identification of an article's motives, objectives, main conclusions, and implications significantly improved in a group of 108 first-year biology undergraduates after a reading course. The rhetorical moves and the scheme are presented in Figure 1.

Apart from structural features, such as the rhetorical structure, metadiscourse is an important rhetorical strategy in academic discourse and one of the most important disciplinary and genre-specific conventions (Hyland, 2005; Hyland & Tse, 2004). An example is the use of *qualifiers*, distinguished in hedges and boosters (Hyland, 2015; Toulmin, 1958). *Hedges* are devices, '(…) which indicate the writer's decision to recognise alternative voices and viewpoints and so withhold complete commitment to a proposition' (Hyland, 2005, p. 52), like 'suggest', 'might', or 'indicate' (Hyland, 1994). Hedges express tentativeness of a statement, while *boosters* express certainty in statements, such as 'demonstrate' or 'obviously' (Hyland, 2005).



Motive	statement why the research was important, leads to the objective
Objective	statement about what the authors want to know (e.g., research question)
Support	statements to justify the main conclusion (e.g., data, interpretations)
Counterargument	statement that argues against the main conclusion or support (e.g., errors)
Refutation	statement that weakens a counterargument
Main conclusion	statement about the main outcome of the study
Implication	statement about the meaning of the main conclusion (e.g., practical application)

Figure 1. Scientific argumentation model (adapted from Van Lacum et al., 2016).

Research question

In the present study, we implemented genre-based writing instruction and SAM in a biology undergraduate course to explicitly draw students' attention to the research article's genre characteristics to support their writing of science texts. Our assumption was that reading the research article genre with the aid of SAM supports students in developing their rhetorical consciousness and that, in turn, might support them in developing scientific writing skills. The writing task for biology undergraduates was a literature review of two research articles. In our analysis, we particularly focused on students' use of rhetorical moves and qualifiers in their written texts, and we aimed to respond to the following research question: *To what extent do first-year biology students make a synthesis of two articles in a written review following their engagement in SAM?* A synthesis was defined as a task in which students select, organise, and connect (research articles') content. Our secondary purpose was to examine the students' reading and writing experiences using SAM and lecturers' perceptions about the students' use of SAM in reading and writing science texts.

Methods

We used a case study in a natural setting that uses a mixed-methods approach to data collection and analysis (Denscombe, 2014). Case studies are particularly focused on gaining deep insight in social phenomena (Denscombe, 2014). This approach was appropriate given that the knowledge base regarding this topic is scarce; hence a case study would allow for an in-depth exploration of students' use of SAM when writing a science text that can be used as input for large-scale studies. We did not intend to generalise our findings to a larger population, but we aimed at an analytical generalisation. Case studies serve 'as a descriptive or exploratory foundation that helps with the development of theory, and it is in this *analytic* respect that the findings from case studies can be

generalized' (Denscombe, 2014, p. 69, emphasis in original). Insights derived from this study may be transferable to other comparable university contexts that make use of a genre-based writing instruction using SAM for scientific writing. Data consisted of students' reviews, student and lecturer interviews, and a student questionnaire. We collected the students' reviews to examine the extent to which the students synthesised two research articles after being introduced to SAM. Next to the students' texts, we took the students' reading and writing experiences using SAM into account using interviews and a questionnaire to enrich and interpret our text analysis findings. We interviewed the lecturers about their perceived experiences of the students' use of SAM in reading and writing in order to gain a more comprehensive and multifaceted overview of the students' abilities of synthesising two articles in a review and the role of SAM in it.

Educational setting

We implemented the teaching strategy in the course Biomolecular Research in 2015 and 2016. We only report about the data collected in 2016, because this course edition was more refined compared to the first implementation. The course lasted three weeks (± 51 h) in the second semester of the first year at a large public research university in The Netherlands. The course focussed on research into Parkinson Disease, aimed at supporting students in developing understandings about molecular biology, essential basic biomolecular laboratory techniques and practicing with reading and writing science texts. The language of instruction was Dutch, though learning material and assignments were provided in English. The course was developed by the researchers in collaboration with the two course lecturers.

Teaching strategy

The core of the teaching strategy was an explicit instruction on research articles' genre characteristics (i.e. the rhetorical structure and qualifiers) by using SAM and practice with reading and analysing research articles about Parkinson Disease (first two weeks of the course, course meetings: ± 19 h). Recent articles from their own research area were selected by the lecturers. The Flesch Reading Ease Score (FRES)[1] of the articles had an average of 29.8 indicating that the articles were very difficult to read. Optional (review) articles were available to students for more information. During small-group meetings students were instructed in different topics about molecular biology and Parkinson Disease, addressing students' subject-matter knowledge that helped them in reading and understanding the research articles. In the meetings, students were explicitly instructed in the rhetorical structure of research articles using SAM. Students were instructed in distinguishing the structure and moves and the use of metadiscourse in research articles by reading a set of different research articles. In addition, they were taught about scientific writing practices and publication processes. To support students in distinguishing rhetorical moves in research articles, we systematically used modelling, one component of the cognitive apprenticeship principle (Collins, Brown, & Holum, 1991). The lecturers illustrated how they identified rhetorical moves by sharing multiple examples from authentic research articles. The first two authors discussed and practiced the use of SAM with both lecturers during the course development. The two lecturers implemented SAM the way that the authors envisioned. Students received three individual reading assignments

with comprehension questions about the biology content and assignments to identify the rhetorical moves (Gillen, 2006), for instance, to identify the motive of the research study. Next, the research articles and the associated assignments were discussed among students and the lecturers.

After the reading tasks (at the end of the first week) students wrote a brief literature review (750–1000 words) in English in which two articles (A: Koyano et al., 2014; B: Fiesel et al., 2015) are compared, evaluated, and synthesised to answer a central question (see the writing task in Appendix 1). In agreement with Spivey (1997), we defined a synthesis as a text in which students select, organise, and connect content from multiple sources, here the two articles. We provided a central question to guide the students' reading and writing. The two articles fitted well together because they present different perspectives on the activation of a Parkinson-related protein (parkin). Article A showed that in parkin activation the protein ubiquitin is phosphorylated by another protein (PINK1) suggesting a two-step model. Article B confirmed the presence of phosphorylated ubiquitin in human patient samples and its dependence on PINK1 activity. Both articles indicated that parkin activation has both a direct and indirect mechanism, whereas article A investigated the molecular mechanism, while article B approached the topic from a pathophysiological perspective. Prior to writing, students answered comprehension questions and mapped the rhetorical moves of both articles. Students gave each other peer feedback on their draft reviews, as peer review may improve students' writing (Nelson, Range, & Burck Ross, 2012), and received additional feedback from the lecturers. The students and lecturers used the following feedback criteria: biology content, line of reasoning, critical evaluation, text structure, and English language use. These criteria were different from our analysis criteria (see below). For the criterion 'line of reasoning' the lecturers were guided by the question: 'Did the student clearly state the authors' reasoning in both papers and give a justified answer to the question addressed in the review?'. However, in their feedback to students the teachers mostly neglected this aspect. The feedback was more focused on the other aspects (e.g. scientific content), aspects that are beyond the scope of our research, and did not influence the students' writing much in terms of synthesis writing.

Participants

A total of 21 students participated in the course (no drop-outs). The students were Dutch biology majors between 18 and 21 years old. All students had some experience with reading research articles prior to the course, ranging from one to six articles ($n = 15$) or more ($n = 6$). Eleven students had never written any kind of scientific text (e.g. research report) prior to the course. All students provided their written consent to participate in the study. Two lecturers taught the course, but they were not involved in data collection and analysis. David (pseudonym) was a professor in Molecular Microbiology and Alex (pseudonym) was a professor in Cell Biochemistry. Both had six years of teaching experience at the time this study was conducted.

Data collection and analysis

Students' reviews

All reviews ($n = 21$, final text) were collected through an online submission system, they were anonymized, and they were assigned an identification code. We used a genre analytic

perspective to analyse the reviews (Biber, Connor, & Upton, 2007), as it is an appropriate way to segment a text in various components to identify genre characteristics. We developed an analytical framework to identify the components of the review: aim, rhetorical moves from both articles, comparison between the two articles, evaluation of the articles, and a final conclusion (Appendix 2). The main rhetorical moves of both research articles that constitute their main lines of reasoning were identified and validated by one of the lecturers (an expert in the research field of Parkinson Disease). The analysis followed three steps: selection, organisation and connecting content, which are required when writing a review (synthesis task). Figure 2 provides an overview of the analysis steps alongside an example. The first step in the analysis was to divide the student's text into text units and categorise their main (rhetorical) function corresponding to one of the components in the analytical framework using linguistic, content, and/or organisational features of the text units. Text units were defined at sentence level, sometimes combined sentences when these evidently belong together. It also happened that a phrase within a sentence was taken as a unit. Text units that contained background information about theory, methodology or prior research were called *information moves*, and were also included in the framework (Dudley-Evans, 1994, see Figure 2, text unit 1). In order to explore whether and to what extent the students evaluated the articles' content, we categorised the text units containing an evaluative statement regarding one or both articles. The nature of the evaluative statements (positive, critical, or neutral) was noted. The first step enabled us to examine what content the students included in their text, and specifically what content (rhetorical moves/information moves) they selected from the two articles. After having categorised all text units, in the second step we noted the order and organisation of the text units (i.e. what was the overall text structure?). In the third step (not shown in Figure 2), we examined whether the student connected the two articles by assessing whether the final conclusion provided by the students answered the central question given the review's content. Next, we analysed how the students made use of qualifiers in their final conclusions, because qualifiers (i.e. hedges or boosters) are an important linguistic characteristic of scientific writing and could provide us with clues about the strength or weakness a student assigned to a conclusion in light of their interpretation and evaluation of the research articles' content (Hyland, 2015). We marked these words in the student's text using a priori codes. Grammar, spelling, and other linguistic features were not analysed, since these are not genre characteristics.

In order to establish trustworthiness, the first and second author discussed the analysis steps prior to the analysis and collaboratively analysed one sample text. Then the first and second author discussed a randomly selected part of the total sample ($n = 5$), showing much agreement. Cases of disagreement were discussed until consensus was reached. Next, the first author analysed all texts ($n = 21$) using an adapted version of the analysis steps and framework.

Students' and lecturers' perceptions about using SAM

For the purpose of examining students' perceptions about their engagement in SAM we carried out semi-structured interviews with them. The first author interviewed nine randomly selected students individually at the end of the course (see Appendix 3 for the interview questions). We carried out pilot interviews with students during the first course implementation to validate the questions. The interviews (lasting ± 30 min) were audio-

Analysis steps

1. *What content does the student select and use?* Divide text into text units and categorize their main (rhetorical) function with reference to the components in our analytical framework using linguistic, content, and/or organizational features of the text unit.
2. *How is the text organized?* Note the order of the text units to provide an overall text structure.
3. *How does the student connect the two articles?* Assess whether the final conclusion in the text answers the aim with reference to the content provided.
   a. Code qualifiers, if present, in student's the final conclusion.

Excerpt data analysis

Introduction

[Text unit 1: Mutations in pink1 and parkin, proteins related to mitochondrial damage control, have been shown to be responsible for recessive early onset Parkinson's disease.[1] This is due to the sensitivity of dopaminergic neurons to mitochondrial damage. Pink1 and parkin proteins are involved in a pathway that induces mitophagy. Where pink1, which becomes stable after depolarization of the mitochondrial membrane, acts as a kinase upstream of parkin. Activated parkin subsequently ubiquitinates certain substrates, leading to mitophagy[2].**] [Text unit 2:** Recently two papers have been published, Koyano et al. (2014)[3] and Fiesel et al. (2015)[4], proposing that pink1 phosphorylates not only parkin but ubiquitin as well. This phosphorylated ubiquitin (also called pS65-Ub) supposedly plays an important role in activating parkin.**] [Text unit 3:** This review will compare these two publications and discuss their content and argumentation.**]**

Analytical framework (first part shown)

Components of review			Text unit
Aim		Central question in the task: Does (and how does it do this?) PINK1 activate parkin directly, indirectly, or both? OR other aim.	3
Article A	M	It is poorly understood how the E3 activity of parkin is accelerated by damaged mitochondria.	
	O	What is the genuine substrate of PINK1 responsible for parkin activation?	2
	MC	Ubiquitin is phosphorylated by PINK1 to activate parkin.	2
	I 1	A complete understanding of the molecular mechanism underlying parkin activation is expected to clarify pathogenesis of hereditary and sporadic forms of PD.	
	I 2	This article shows for the first time ubiquitin phosphorylation and its significance.	

Note. M: Motive, O: Objective, MC: Main Conclusion, I: Implication.

Figure 2. Analysis steps with an excerpt of the data analysis of student 8's review. In parentheses text units are indicated. The underlined word in the student's review is coded as a hedge.

recorded and transcribed verbatim. We marked fragments in the transcripts related to the students' experiences about using SAM during their reading and writing. These interviews were supplemented by a questionnaire that was filled out by 20 students after the last course meeting (see Appendix 3). We performed a pilot test of the questionnaire during the first implementation testing the comprehensibility of the items. The students had to indicate how much they agreed (on a five-point Likert scale) with four statements about the usefulness of SAM in reading. We calculated median scores for each statement.

In addition, the students were asked to answer three open-ended questions about the difficulties they might have experienced during move identification, reading research articles, and writing the review. Their answers were categorised according to the type of difficulty.

To examine the lecturers' viewpoints, the first author interviewed them individually after the course to identify their perceived experiences with the course and the students' use of SAM (see Appendix 3 for the interview questions, pilot tested in the first course implementation). The interviews (± 45 min) followed a semi-structured format and were audio-recorded. Audio fragments were analysed and summarised. The summaries were sent to the lecturers for verification, after which small adjustments were made.

Findings

Students' reviews

Content selection

The students included most rhetorical moves from the original articles in their texts, particularly the objectives, supports and main conclusions as shown in Table 1. Article A's motive was mentioned more often than article B's motive, maybe because article A's motive and objective are more directly linked with the aim of the review. The counterargument in article B was included more often than the one in article A, because it was probably easier to recognise since it was stated in the discussion section, a typical place for counterarguments. Refutations and implications were included by less than half of the students. Apart from the findings on counterarguments and refutations, the findings suggest that the students identified most components of the authors' arguments.

Seventeen students compared the two articles with respect to their objectives, methods, results, and/or conclusions. Nineteen students evaluated both articles, often on multiple aspects, mostly on text structure/line of reasoning and the methods used (see Table 2). Overall, positive evaluations had the upper hand. Article B was criticised more often than article A (42 vs. 34 instances, not shown in Table 2). In most cases, the evaluations were neither further explained nor supported. Sometimes it was simply stated that it impacted the results, or that a method, like using patient samples, was more reliable than another method without explanation.

Content organisation

Three types of structures in the students' reviews emerged, which we described as summary-based, topic-based, and evaluation-based, as explained in Figure 3. In most

Table 1. Number of student texts ($n = 21$) containing rhetorical moves. Article A: Koyano et al. (2014). Article B: Fiesel et al. (2015).

Article	M	O	S	CA	R	MC	I
A	12	15	21 (students mentioned 3–9 supports, total 9)	1	0	18	3 (students mentioned 1 out of 2 implications)
B	2	12	21 (students mentioned 2–6 supports, total 6)	12	3	12	6 (students mentioned 1 out of 3 implications)

Note: M: Motive, O: Objective, S: Support, CA: Counterargument, R: Refutation, MC: Main Conclusion, I: Implication.

Table 2. Topics of evaluation in students' reviews. Indicated is the frequency of positive (+), critical (−), or neutral (±) evaluation statements.

Topic of evaluation	Nature (frequency)	Examples
Text structure / line of reasoning	+ (15) − (5)	'Koyano et al. found more substantial data than Fiesel et al. and their line of reasoning was clear and well explained.' (+, student 1, unit 31)
Methods	+ (19) − (4)	'In my opinion they are not wrong to draw that conclusion but I would like to see more tests to prove that pS65-UB is specific to only mitochondrial damage and occurs in all cell types.' (–, student 21, unit 16)
Data / results	+ (4) − (2)	'In contrast, Fiesel et al, have a main support based on experiments solely with their own antibodies, which weakens their statements.' (–, student 7, unit 22)
Counterarguments	+ (1) − (8) ± (2)	'Furthermore, the experiments where described in detail and there seemed to be no hard counterarguments.' (±, student 11, unit 21)
Conclusions	+ (1) − (2)	'Even though Fiesel et al.[2] experiments and supports weren't as clear as Koyano et al[1], they might have provided evidence that can be used for therapeutic purposes, which in my opinion is more a far-reaching finding.' (+, student 13, unit 18)
Relevance of information	+ (7) ± (1)	'However, the in vivo part of their study was quite interesting, but not relevant for this review.' (±, student 17, unit 19)

texts ($n = 12$) a topic-based structure was evident, like the review by student 8. In the interview he explained: '[the authors from both papers] are actually proving the same thing only using different methods. I have bundled that together in different sub headings' (I8). The summary-based structure and the evaluation-based structure were found to a lesser extent.

Content connection

We analysed whether the students connected the content of both articles in answering the central question. Seventeen texts contained both an aim (i.e. the (paraphrased) central question) and a final conclusion. In most texts, we observed a connection of the content of the two articles, however in varying ways. The degree of connection was irrespective of the text's structure. In eight of these texts, the articles were fully connected: information from the two articles was used to answer the aim correctly. A few of those students weighed the relevance of the two articles for their answer, as student 6 did:

> It was clear that the article by Koyano et al. was more relevant for my main conclusion than that of Fiesel et al., because Fiesel et al. mainly described physiological events of phosphorylated ubiquitin. Therefore, most information revealed by Fiesel et al. was not of importance for my review (student 6, unit 25).

Below we share an example of a student connecting the two articles in an explicit manner:

> In Koyano et al. [1] they found that PINK1 was responsible for UB phosphorylation. In the article of Fiesel et al. [2] the [*sic*] confirmed these findings with similar results. The authors of Koyano et al. [1] also showed that although PINK1 phosphorylates Parkin, it remains inactive without interaction with pS65-UB. Given the results of both articles I conclude that PINK1 activates Parkin both directly and indirectly upon (simulated) mitochondrial damage (…). (student 16, units 20–22)

These texts came closest to a synthesis, as the students formulated a new conclusion based on the preceding statements. In six other texts, there was a constrained connection of both

Summary-based (n = 6)	Topic-based (n = 12)	Evaluation-based (n = 3)

• Introduction (background information, aim)
• Summary article A
• Summary article B
• Comparison and/or evaluation articles
• Final conclusion
	• Introduction (background information, aim)
	• Main text
	  ○ Topic 1
	  ○ Topic …
	• Comparison and/or evaluation articles
	• Final conclusion
		• Introduction (background information, aim)
		• Main text
		  ○ Discussion article(s) + Evaluation and/or comparison
		• Final conclusion

Figure 3. Organisation of sections in three types of review structures.

articles. In these texts, the conclusion was correct with respect to the stated aim, but was mainly based on one article. Or the text lacked important information, resulting in an unjustified final conclusion. In another three texts the final conclusion did not answer the aim correctly and/or did not follow completely from the preceding information, resulting in an incorrect argument. We also observed that students did not incorporate their evaluative statements in their final conclusions, as illustrated by the following fragment:

> In contrast, Fiesel et al. have a main support based on experiments solely with their own antibodies, *which weakens their statements*. Also disregarding the fact that their antibodies recognized both parkin and ubiquitin phosphorylated versions in simply fixing their error margin, *weakens their conclusions*. All in all, *Koyano et al. and Fiesel et al. have given enough support* to show that ubiquitin is phosphorylated by PINK1 and is a co-factor in activating parkin. (student 7, units 21–24, emphasis added)

Although most students did compare and evaluate the articles' content on various aspects, this information was little or not visible in their (formulation of the) final conclusion. Our analysis of the use of qualifiers in their final conclusions ($n = 19$) showed that four students used a booster ('have given enough support', 'support the already convincing', 'show', 'obvious') and four students included a hedge ('suggest', 'it could be concluded', 'indicate', 'implies'). While article A drew conclusions with some caution, this was not always visible in students' final conclusions.

Students' perceptions about SAM

The questionnaires showed that all twenty students overall agreed about the usefulness of identifying rhetorical moves for understanding research articles, during the course, but also in the future (Table 3).

From both the interviews and questionnaire, we observed that identifying moves (esp. motive, objective, supports, counterarguments, and refutations) was difficult for students, but that practice helped. The students mentioned difficulties with distinguishing between motive and objective, with determining the importance of supports, and with the identification of counterarguments and refutations. The students indicated in the questionnaire that the articles were sufficiently comprehensible, but they found reading often difficult caused by a lack of background knowledge and knowledge of scientific language. Yet, lectures and discussions during the meetings helped the students in reading: 'With the SAM, understanding the main reasoning from the articles was a lot easier. After the lectures, the experiments were clear' (Q5).

Sixteen students indicated in the questionnaire that they encountered difficulties in writing the reviews. Most students had difficulty with the selection of information and

Table 3. Median scores about the students' perceptions about SAM ($n = 20$).

Statements	Median score (span)
The illustration of the different elements (e.g. motive) by the lecturers was helpful to understand the different elements in research articles.	4.0 (1–5)
The article discussions were helpful to understand the research articles.	4.0 (1–5)
It is useful to identify different elements (e.g. motive) to understand a research article.	4.0 (2–5)
In future, I will look for the different elements to understand a research article when reading one.	4.0 (3–5)

Note: A five-point Likert scale was used (1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree).

with the format of a review. In the interviews, the nine students mentioned most frequently difficulties with content selection, critical evaluation, expectations of a review's format, and using scientific language. Seven of the nine interviewed students found the focus on SAM in the research articles during the course helpful for writing the review. Main reasons were that it helped in understanding the articles and organising the important content. Summing up the above, the analysis of the data shows that the students perceived SAM as a useful tool in understanding the research articles, while experiencing sometimes reading and move identification difficulties. Writing the review was considered as a difficult task by most of the students, particularly content selection. Still, the interview findings suggest that SAM was of use in writing the review, mainly in terms of organising and understanding the content.

Lecturers' perceptions about SAM

According to Alex most of the students learned to extract the most important information from a research article in a reasonably simple and fast way. He observed that students read an article faster at the end of the course compared to the start, which had probably to do with their increased subject knowledge, but also with their new reading strategies. David believed that, after the course, the students know that they can read a research article by themselves, and that they have a more comprehensive view of how science works. Both lecturers perceived that the students' reading ability was at a good level at the end of the course. David indicated that generally the students understood the main message in the articles and were able to identify the important content. Both lecturers said that the majority of the students did not understand the articles' methods in detail. The lecturers agreed on the usefulness of SAM for students in reading research articles, mainly in selecting the most important information. SAM was helpful for David when he discussed the articles with the students: 'It prevents to getting lost into details'. Both lecturers indicated that the supports are difficult to find in research articles, because the texts have a high information density. Alex thought it is better to look for the more general, preliminary conclusions (a generalisation of a finding). David believed that the students saw the relevance of SAM, but that it is difficult to identify each rhetorical move in an article: 'that is difficult, we, as teachers also have discussion about that'. He experienced that students often think in terms of 'right' or 'wrong' when searching for rhetorical moves in articles, while their reasoning in identifying a particular text fragment is more important.

Both lecturers were satisfied with the level of the students' reviews. In particular, the text structure was excellent, said Alex. Both noticed that some students had difficulty in making a synthesis in their texts, which is in accordance with our text analysis findings. Alex mentioned that some students found it difficult to combine the results of the articles and draw a final conclusion. David added that some students were clearly better in making a synthesis compared with other students. Lastly, many students did well in critically evaluating the articles, said Alex, although students formulated their evaluation as a personal opinion (e.g. 'I think this article was not very good, because of … '). David emphasised the difficulty students had in their evaluation. Both lecturers thought that SAM was useful in helping students to write the review. Rhetorical moves from both articles appeared in the students' reviews, they explained. Alex mentioned that SAM helped students mainly in organising their text. Summing up, the findings show that the lecturers perceived SAM

as useful for supporting students in reading research articles in terms of selecting the most important information of the text, as well as bringing structure in a text when writing the review.

Discussion and conclusions

In carrying out this study, we departed from the assumption that a reading-based writing task (from a reading-writing perspective) and explicit instruction in the genre characteristics of research articles (following a genre-based writing instruction) can help students in scientific writing. We hypothesised that SAM would be used as a heuristic helping students to understand the main argument put forward in a research article by explicitly developing their rhetorical consciousness needed for writing a science text. Based on these assumptions we implemented a teaching strategy for science writing in an undergraduate biology course. We aimed at exploring which genre characteristics (i.e. rhetorical moves and qualifiers) first-year biology students used in writing a literature review, a form of synthesis writing, of two complementary articles. In what follows, we discuss the findings of the study as response to our main research question: *To what extent do first-year biology students make a synthesis of two articles in a written review following their engagement in SAM?* We expected that the reviews required selection, organisation, and connection of information from both articles, leading to a synthesis. Based on our findings, we conclude that most students did make a synthesis of the two articles and suggest that SAM could be used as a first step in understanding and grasping an article's content, selecting and organising important moves when writing a review. SAM might prepare students for writing a review in terms of selecting and organising content of the source texts. Van Ockenburg, Van Weijen, and Rijlaarsdam (2019) showed that a similar activity, in which students answer questions on the main ideas of a text, is effective in selecting and organising content in synthesis writing.

The findings showed that the students distilled and selected most rhetorical moves from both articles for their text, especially the objective, supports and main conclusion. The findings about the students and lecturers' perceptions about using SAM showed that they perceived SAM as useful for reading and understanding research articles, mainly in getting an overview of a research article and selecting important information. The students found some move identifications difficult, especially the main supports and counter-arguments. These findings correspond with those by Van Lacum et al. (2014). Our findings suggest that the students identified and probably grasped the authors' arguments, although the students did not fully comprehend the articles' details. It is well-documented in literature that students' scientific argumentation depends on their familiarity with scientific content (Von Aufschnaiter, Erduran, Osborne, & Simon, 2008). We must be aware that our students are novice readers and incidental audiences for research articles (Yore, Bisanz, & Hand, 2003). Studies have indicated the difficulty of reading research articles for novices, due to the high information density, technical vocabulary, and abstract language (Fang, 2005; Gillen, 2006). Some students noted their unfamiliarity with the use of scientific English, however, studies have indicated that Dutch students have a very high English proficiency (EF, 2016), and therefore we maintain that this had no impact on their comprehension. While SAM appears to be supportive for understanding the rhetorical structure of a research article, it does not guarantee a full comprehension of the

content. Although we invested a lot in explaining the content of the research articles, additional instruction in combination with SAM might stimulate students' rhetorical consciousness.

The students' reviews were organised according to three text structures (summary-, topic-, and evaluation-based), which did not correlate with the extent to which the students connected the two articles. Spivey (1997) indicated that writers often follow or repeat a source text in synthesis writing. This was evident in the students' texts with a summary-based structure in which the two articles were summarised consecutively. The students' task representation could have been of influence, as students might conceive a synthesis task as summarising source texts (Mateos & Solé, 2009). Future studies could improve our understanding of the way students synthesise research articles in review tasks. In the other two structures, the students combined and organised the content less consecutively, which reflects the variability in synthesis writing. Most students and the lecturers perceived SAM as useful in structuring and organising important information for the review.

The findings of the study illustrate that the majority of the students' reviews contained an evaluation. The students evaluated the articles mainly on the line of reasoning, as was asked for in the writing task, and on the methods. The evaluative statements by the students were often not elaborated nor did they sound in the final conclusions. This finding concurs with the literature indicating that novices' critical evaluation skills and content knowledge restrict them in evaluating an article's argument (Gillen, 2006; Yore et al., 2003). Although this has been discussed in the lectures only a small number of students ($n = 8$) used a qualifier in their final conclusion. And if students used qualifiers, they did not always chose the ones corresponding to their evaluation of the articles. These findings suggest that students had problems with the rhetorical meaning of qualifiers in science texts.

The students and lecturers indicated difficulties with writing, such as content selection. Studies have shown that undergraduate students experience difficulties with writing from sources (Mateos & Solé, 2009; Zhang, 2013), but that they develop certain strategies to deal with these complex processes (Cumming et al., 2016). We note that there was no extensive instruction or practice in synthesis writing during the course. To better support students in connecting and justifying content, we should address synthesis writing more explicitly in the course by including effective learning activities (Van Ockenburg et al., 2019), practice and feedback.

Some characteristics of our teaching design could have affected our conclusions. The small sample size means that we should be careful in drawing conclusions. The selected research articles were complex and we should be cautious with our interpretations about students' text comprehension reflected in their writing. Using a review as a writing task has also a shortcoming in this respect, because novice writers tend to paraphrase, and even copy text from textual sources: a phenomenon often observed in writing from sources tasks (Keck, 2006). This could have influenced the way in which students' texts were phrased, and could have hide, for instance, an incomplete text understanding and their recognition of the text's rhetorical structure.

From our analysis of students' texts, we got indications that SAM is a useful heuristic with regard to the structural elements in comprehending and setting up a science text. We also found that students and lecturers perceived SAM as a useful heuristic for reading and

understanding research articles and for selecting and structuring the content when writing a review. This is exactly what we intended with our course, which was developed from a genre-based approach and the perspective of Swales (1990) construct of rhetorical consciousness: the recognition of a genre's rhetorical structure. As other researchers have found, students' understanding and recognition of this structure can help them in reading and writing (Grabe, 2001, 2003; Grabe & Zhang, 2016). Our findings suggest that SAM is helpful in explicitly drawing students' attention towards the rhetorical structure of research articles when reading and writing a literature review. It would be promising to investigate whether students could apply SAM when writing other science texts, like a laboratory research report. Based on the findings of this study, we recommend a larger follow-up study to measure students' reading and writing abilities after having followed a course in which SAM is used, and to examine the potential effectiveness of SAM on students' scientific reading and writings skills. Another possible future study would be an examination of the role of the lecturers in implementing SAM and giving feedback to students' texts to provide important input for the design of professional development programmes and university writing courses.

Note

1. The Flesch Reading Ease Score (Flesch, 1948) is a measure for text readability on a scale between 0 (very difficult to read) and 100 (very easy to read).

Acknowledgements

We would like to thank Arjan Kortholt and Dirk-Jan Scheffers and all students for their willingness and enthusiasm to participate in the study.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendices

Appendix 1. Writing assignment

Write a review based on the articles by Koyano et al. (2014) and Fiesel et al. (2015) in which you give an answer to the following question:

Does (and how does it do this?) PINK1 activate parkin directly, indirectly, or both?

The review should contain:

- A description of the content and the argumentation of both articles.
  - For the articles' argumentation: include how the authors came to their main conclusion(s) (what is their line of reasoning?).
- A critical evaluation about the way the authors of both articles justified their main conclusion (s). Do you agree with the main conclusion(s) based on the given supports? Why do you (not) agree?
- A comparison of both articles with reference to the question addressed above.

Guidelines:

- The length of the review should be between 750 and 1000 words.
- You could use your completed tables with elements of both articles as a support to write the review.
- Take your fellow biology students who do not know the articles as the audience for your review.
- Keep in mind the criteria of the peer review form.

Appendix 2. Analytical framework reviews

Review student: …				
Components of review			Text unit	Remarks
Aim		Question in the assignment: Does (and how does it do this?) PINK1 activate parkin directly, indirectly, or both?		
Article Koyano et al. (2014)	M	It is poorly understood how the E3 activity of parkin is accelerated by damaged mitochondria.		
	O	What is the genuine substrate of PINK1 responsible for parkin activation?		

(*Continued*)

Continued.

		Review student: …		
		Components of review	Text unit	Remarks
	MC	Ubiquitin is phosphorylated by PINK1 to activate parkin.		
	I 1	A complete understanding of the molecular mechanism underlying parkin activation is expected to clarify pathogenesis of hereditary and sporadic forms of PD.		
	I 2	This article shows for the first time ubiquitin phosphorylation and its significance.		
	S 1	ubiquitin is phosphorylated by PINK1.		
	S 2	the phosphorylation site on ubiquitin is Ser65.		
	S 3	PINK1 is required for ubiquitin phosphorylation.		
	S 4	(about the role of phosphorylated ubiquitin): parkin conjugates both unphosphorylated and phosphorylated ubiquitin to substrates.		
	S 5	phosphorylated ubiquitin activated parkin.		
	S 6	ubiquitin phosphorylation at Ser65 is essential for parkin activation (experiment in yeast system).		
	S 7	Activation of parkin is allosteric (the molecular mechanism by which phosphorylated ubiquitin activates parkin).		
	S 8	phosphorylated ubiquitin interacts physically with parkin.		
	S 9	The presented model in Figure 4j. (is a speculation, use of computational modelling)		
	CA + R	The absolute level of endogenous ubiquitin was very low, but it might be a significant pool due to the pleiotropic functions of ubiquitin.		
Article Fiesel et al. (2015)	M	The (patho-)physiological significance (in neurons and brain) of ubiquitin phosphorylation is unknown.		
	O	Generate novel antibodies and assess pS65-Ub signals *in vitro* and in cells (demonstrate the (patho-)physiological relevance).		
	MC	1. The authors confirmed the presence of pS65-Ub in stressed primary neurons and *in vivo* in human postmortem brains. 2. The two pS65-Ub antibodies can be used as a tool to monitor mitochondrial damage in cell models and brain tissue.		
	I 1	Additional studies are needed to further investigate pS65-Ub functions and explore its potentials for biomarker/therapeutic development.		
	I 2	The nature and composition of pS65-Ub-positive structures must be exactly determined from larger case studies.		
	I 3	pS65-Ub should be further analyzed in different genetic or environmental animal models of PD.		
	S 1	two pS65-Ub antibodies were validated in vitro.		
	S 2	cellular pS65-Ub signal is induced by stress and amplified by functional Parkin.		
	S 3	pS65-Ub is specific to mitochondrial damage in all cells.		
	S 4	pS65-Ub depends on PINK1 kinase activity and is reversible.		
	S 5	pS65-Ub in human patient's fibroblast-derived and primary mouse neurons.		
	S 6	pS65-Ub in human postmortem brain. + pS65-Ub positive mitophagy granules accumulate with age and disease in human brains		
	CA	Results suggested a much greater cellular abundance of pS65-Ub over pS65-Parkin. Though it was not noticeable in the staining pattern, they could not formally exclude some minor contribution of pS65-Parkin cross-signal to the staining obtained with pS65-Ub#2.		
	R	Ubiquitin and Parkin are both PINK1 substrates and jointly act as important regulators of the mitochondrial quality control pathway.		
Comparison of articles				
Evaluation of articles				
Final conclusion				
Other components (e.g., information moves)				

Note: M: Motive, O: Objective, S: Support, CA: Counterargument, R: Refutation, MC: Main Conclusion, I: Implication.

Appendix 3. Interview questions and student questionnaire

Student interviews (translated to English)

1. Introduction to the student
   - Permission to record the interview on audio?
   - Data will be treated confidentially and anonymously.
   - A short introduction about the aim of the research and this interview:
     - *Research aim:* gaining more knowledge into the way first-year students learn to write scientifically.
     - *Interview aim:* reflecting on your approach for writing of the review and evaluate the course.
     - The interviewer will not assess your review or skills.
   - The interview will last for a maximum of half an hour.
   - Please indicate when a question is not clear to you or when you have questions.
2. Review

   Please try to recall and remember the moment you were writing the review.

   Questions (and probing questions):

   - Did you have any difficulties in understanding the studies in the two articles (the method and the results)? If yes, what difficulties?
   - Did you recognise the line of reasoning in the two articles? (clarify, if needed, by referring to the different rhetorical moves)
   - Did you have any difficulties in writing the review? If yes, what difficulties?
   - Did you have any difficulties with writing the review in English?
   - Do you think that the focus on structure and key elements (i.e. SAM) in research articles helped you to write a review? Why or why not?
   - What is you experience with identifying key elements in research articles? (Was it useful? Was it difficult? Were some key elements more difficult to identify than others? If so, which and why?)
   - Do you have any questions, additions or remarks?

Student questionnaire

1. Please indicate how much you agree with the following statements. The numbers have the following meaning *(Put your answer behind each statement)*:

   1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

   a. The illustration of the different elements (e.g. motive) by the lecturers was helpful to understand the different elements in research articles.
   b. The article discussions were helpful to understand the research articles.
   c. It is useful to identify different elements (e.g. motive) to understand a research article.
   d. In future, I will look for the different elements to understand a research article when reading one.

2. In general, which of the seven elements did you find hard to identify in the research articles? *(Highlight your answer(s))* None, Motives, Objectives, Main conclusions, Implications, Supports, Counterarguments, Refutations

If you find one or more elements hard to identify, please shortly explain why:

3. Did you have any difficulties in reading the research articles? Yes / No

   If yes, please explain which difficulties you had:

4. Did you have any difficulties in writing the review? Yes / No
   If yes, please explain which difficulties you had:

Lecturer interviews (translated to English)

1. Introduction to the lecturer
   - Permission to record the interview on audio?
   - Data will be treated confidentially and anonymously.
   - A short introduction about the aim the interview: reflecting on the course and working with SAM.
   - The interview will last for a maximum of 45 min.
   - Please indicate when a question is not clear to you or when you have questions.
2. Interview
   - How did you experience the first part of the course (related to the use of SAM)?
   - What went well in the course and what not?
   - Do you think the research articles were appropriate for the course?
   - Do you think that the students understood the research articles?
   - To what extent did the students achieve the learning goals?
   - What do you think the students learned from the course? What are bottlenecks?
   - How did you experience working with SAM?
   - How did the students experience using SAM, according to you?
   - Could they work well with SAM?
   - Do you think using SAM helped the students with reading research articles? Why or why not?
   - Do you think using SAM helped the students with identifying the line of reasoning in research articles? Why or why not?
   - Do you think using SAM helped the students with writing the review? Why or why not?
   - What is your impression of the students' reading abilities after the course? Why?
   - What is your impression of the students' writing abilities after the course? Why?
   - What do you think of the writing quality of the *first* drafts of the review? Why?
     - and more specifically, the line of reasoning in the reviews?
   - What do you think of the writing quality of the *final* drafts of the review? Why?
     - and more specifically, the line of reasoning in the reviews?
   - Do you have any questions, additions or remarks?